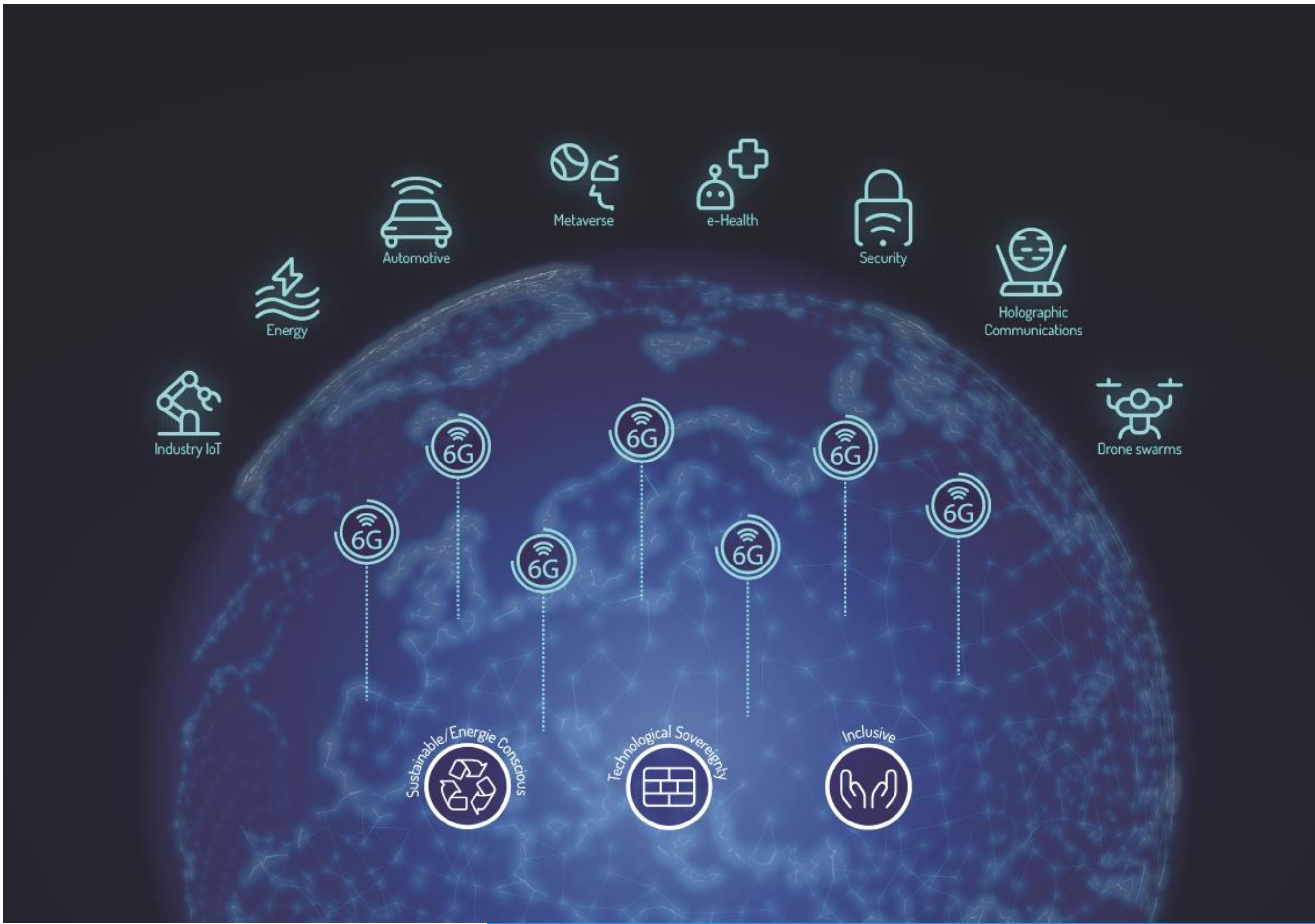

6G Smart Networks and Services Industry Association (6G-IA)

White paper

EMERGING 5G AND BEYOND ECOSYSTEM BUSINESS MODELS

DOI: 10.5281/zenodo.14756404

URL: https://doi.org/10.5281/zenodo.14756404

EXECUTIVE SUMMARY

The telecommunication industry is currently adapting to the changes in market dynamics brought about by the new services and features, introduced with the transition from 4G to 5G and under discussion as the industry moves to the forthcoming 6G. The underlying industry challenges are to understand the new business opportunities created by the virtualisation of information and communication technologies (ICT) and to ensure companies are best placed to maximise their delivery of value to the 5G and Beyond 5G (B5G) markets. Although early in the development cycle, it is expected that similar issues will arise with the future deployment of 6G networks, and so it is important for the economic viability of those networks to consider value creation in parallel with the on-going technology development.

The 6G Industry Association (6G-IA) [1] sub-working group *Business Validation, Models, and Ecosystems* (BVME-SG) has reacted to these challenges by previously publishing the white paper *5G and Beyond 5G Ecosystem Business Modelling*. This new white paper builds on and extends that prior work, by presenting a focused application of the business modelling framework. To guide the discussion, the Industry 4.0 (I4.0) vertical is taken as an exemplary implementation that can be easily adapted and reproduced by other verticals.

The proposed framework consists of five steps that are intended to support stakeholders in the 5G/B5G ecosystem to explore business opportunities and understand how variations in ecosystem configurations can affect their operations. The result of the implementation of those steps shows that the framework is capable of uncovering key insights affecting many strategic questions arising from the changes in ecosystem dynamics. The white paper also considers how the analysis extends to 6G, providing insights that will be useful when exploring business opportunities that arise as 6G technology develops in the near future.

This white paper also explores the question of cost resulting from ecosystem variations, first at a high level of abstraction (e.g., to identify opportunities to create synergies, competitive tensions and economies of scale), second using more detailed approaches to assess the technoeconomic sustainability of the forthcoming 6G ecosystem, a major factor affecting investment decisions and company strategy. That is achieved by re-defining how studies are performed to capture the technoeconomic viability of 5G/B5G ecosystems, i.e., it is proposed to perform the analysis: 1) on a per network deployment basis, for a given scale and set of dimensioning assumptions, and 2) mapped on ecosystem roles towards assessing viability on a per actor/role basis.

The final section of the white paper looks toward the implications expected from the transition from 5G to 6G in terms of additional ecosystem actor roles. The emergence of these new roles is likely to be driven by the end-to-end (E2E) architecture of the 6G networks in terms of being even more distributed and disaggregated compared to current 5G solutions. However, due to the fact that both network generations will be built on distributed and disaggregated design principles, it is expected that the framework presented in this white paper will be equally applicable as the industry moves from 5G to the 6G era.

TABLE OF CONTENTS

1. INTRODUCTION

The evolution from 4G to 5G/B5G, the forthcoming 6G [2] and the supportive advances in system architectures and capabilities are driving market dynamics, influencing and impacting businesses across the telecommunication industry. The challenge that the industry must address is that of adapting to embrace all the new business opportunities brought by the new services and applications. This overarching challenge creates many questions for companies in the 5G/B5G ecosystem on how to optimally position themselves to deliver value in light of the changes to the communication system. The collaboration of stakeholders is pivotal to set the stage for harnessing the full potential of these technologies.

In response to this observation, the 6G-IA sub-working group on *Business Validation, Models and Ecosystems* (BVME-SG) aims to provide tools to guide industry stakeholders in managing business responses to the technology transitions. To this end, the BVME-SG has published in 2023 the white paper *5G and Beyond 5G Ecosystem Business Modelling* [3]. In continuation of the work, the goal of this white paper is to provide an analysis of the implications of implementing the proposed business modelling framework [3], while highlighting insights and commercial considerations emerging from the applications of this approach.

The I4.0 vertical has been selected to perform such an analysis because it has readily defined "problems to be solved", which are quite relevant in the 5G/B5G context [4][5]. The analysis of this vertical, although interesting in its own right, also acts as an exemplary case to follow when assessing other verticals.

A baseline description of the 5G/B5G ecosystem and the actor roles involved are first presented. This is accompanied by examples of companies that can take on these roles, the examples chosen are provided only for illustrative purposes. The 5G/B5G market demonstrates ecosystem characteristics (as discussed in previous white papers from the BVME-SG [6][7]), and so it is insightful to examine the implications of variations in the configuration of this–ecosystem and the impacts these changes can have on individual businesses and on the ecosystem as a whole. The goal of this white paper is to incorporate and demonstrate how such an analysis leads to key questions that companies must address for a sustainable business model to be developed.

The framework introduced in the previous white paper [3] is essentially a generalised tool for achieving these goals, as it helps to derive insights and visualise the impact of variations in ecosystem dynamics. The five steps of the framework are illustrated in Figure 1: and can be summarised as follows:

Step 1 Expand: Elaborates on 5G/B5G ecosystems, with actor roles contributing to solving the problem, while creating and capturing value (Section 2). Here, insights from resources on I4.0 were used e.g., [5], to provide an overview of actor roles.

Step 2 Focus: Examines relevant actor roles, and how they are related in specific ecosystem configurations (Section 2). During this step the following are identified:

- The actor roles that contribute to creating a solution and value for the vertical customer in I4.0.
- The ecosystem configurations, relevant for delivering the value to a vertical customer in I4.0.
- The business models for the different actor roles.

Step 3 Design: This is considered from the perspective of one firm or actor, with the goal of determining its key actions for a specific ecosystem configuration (Section 3). During this step, the firm/actor:

- Considers several ecosystem configurations, actor roles and business models, adopting the insight collected from the visualisation of these various configurations.
- Becomes aware of how other actors and actor roles are affected by different strategies and changes in the configuration of the wider ecosystem.
- Identifies alternatives, which seem plausible to emerge, and assesses them.

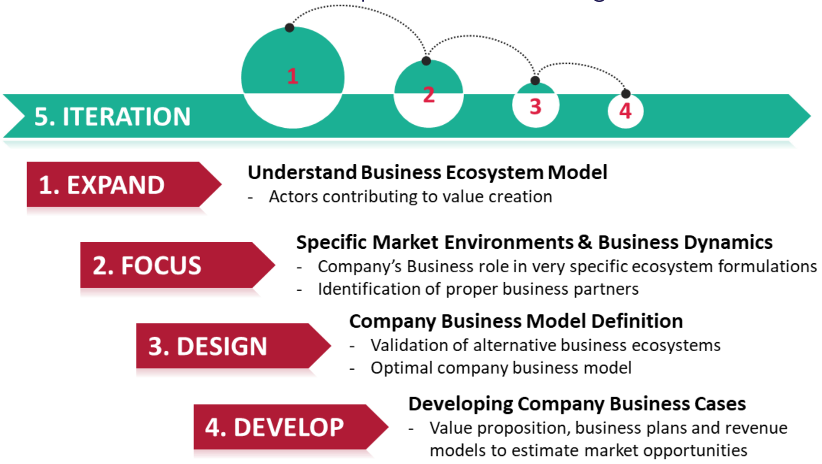

Figure 1: Five steps for ecosystem business modelling [3].

In this white paper, we do not consider **Step 4 Develop,** where one firm chooses to conduct a detailed investigation of alternative ecosystem configurations, resulting in specific business planning and quantification. This is the step that eventually provides different price and revenue models. In our business model exploration in Step 2, we have suggested revenue models for different actor roles, however, they will need further development to elaborate more precise business plans. Finally, we also do not implement **Step 5 Iteration,** which underlies the whole framework, helping to ensure the dynamics of the ecosystem are continually assessed and market changes can be effectively reacted to in a timely manner.

This white paper is divided into two major sections: Section 2 introduces the problem to be solved and lists the active actor roles in the I4.0 ecosystem. This baseline information is then used to elaborate on the ecosystem and business models that may emerge for the various actor roles. Section 3 starts with a series of questions that must be considered when developing a strategy for taking on new business opportunities within an active ecosystem. The discussion that follows supports actors in analysing opportunities with a series of techno-economic considerations that need to be understood in order to create a sustainable business model for delivering value to users and customers in I4.0. Section 3 concludes by looking towards the likely implications on ecosystem actor roles that will occur with the transition from 5G to 6G.

2. VERTICAL USE CASE I4.0 AND 5G/B5G ECOSYSTEM BUSINESS MODELS

I4.0 refers to the fourth industrial revolution, which is currently ongoing in manufacturing environments [8]. The term signals how factories and industrial plants take advantage of technology advancements to improve flexibility, versatility, usability and efficiency across the entire value chain [5].

This white paper focuses on how a 5G/B5G ecosystem can create value for I4.0. I4.0 stakeholders have voiced that there are "problems to be solved" in their sector [4][5]. This creates the opportunity where value can be created by solving these issues, as there is a customer-base willing to pay for such solutions. Furthermore, the addressable market for solutions is large, as there are 1 million factories worldwide, while manufacturing is often the largest onshore industry when considering contributions on a country-by-country basis [9].

Problems in I4.0 must be solved by an ecosystem consisting of many actor roles. Thus, I4.0 has the characteristics calling for ecosystem analysis to realise the market opportunity. With this problem description as a starting point, we can next introduce the actor roles in the ecosystem that contribute to the solutions. We can then elaborate on which ecosystem and business models may emerge for the various actor roles in the ecosystem.

2.1. I4.0 CHALLENGES

We rely on the previous analysis of I4.0 problems that need to be addressed [4][5], summarised in Table 1. We are not going to elaborate on these problems, rather take them as a validated starting point for analysing actor ecosystem roles and their business models.

One main problem is that current wired connectivity heavily limits mobility and flexibility. In summary, manufacturers want to utilise the flexibility of deployment and mobility allowed by wireless links, coupled with the performance and reliability of current wired networks. Moreover, there are problems with interoperability across systems and networks, and indoor and outdoor environments. Further flexibility could be achieved with virtualisation of hardware (HW), such as programmable logic controllers (PLC), which are important in industrial contexts. This all calls for standardisation, which is reinforced by the need to enable economies of scale in production of 5G and B5G industry devices.

On a more general note: with the use of wireless combined with other technologies (such as IoT devices, AI-driven applications deployed on the edge), manufacturers and plants could improve working environments. Finally, the sector calls for cost-efficiency, with the underlying assumption that investments should be taken by someone who could, in turn, share the costs between many parties by providing key capabilities delivered as a service.

Table 1: I4.0 challenges to be solved by connectivity solutions, as seen from the Manufacturer point-of-view.

Problem	Benefit/Value proposition
SOLUTION PERFORMANCE	
Reduced mobility due to wired connectivity • long lead times for cabling new equipment • location of devices is static - little flexibility	5G connectivity would provide a totally new way of operating factory floor due to: • Time efficiency • Mobility • Flexibility while keeping key performance indicator (KPI) of cabled connectivity. Other keywords: • freedom of movement for vehicles and devices • smart manufacturing applications are time-critical, i.e. affect KPIs **Constraint**: access to spectrum
Challenge to maintain time-critical aspect of applications	If different edge computing solutions were available, low enough latency could be achieved for industry applications if e.g., 5G synch – time-criticality could be solved.
Huge hurdle having to use different non-compatible connectivity means across outdoor and indoor	If 5G connectivity was available, seamless indoor and outdoor connectivity could be achieved at plant.
Problem to digitize across systems because of information silos and data management	If there were available standards across connectivity and systems - benefits of digitization could be achieved faster with less costs - in all domains important to factory operators.
Wireless technologies struggle to deliver determinism, reliability, and latency at levels of wired connections	If 5G could deliver - as wired, cabled connectivity - the same level of determinism and latency —> the combination of performance and mobility is unbeatable **Constraint**: access to spectrum
Industrial devices, PLC are hard-coded	If 5G evolution could lead to virtualisation of devices, flexibility and QoS could be ensured.
Systems are energy greedy	If 5G could be energy efficient, digital solutions could be implemented in a sustainable and cost-efficient way.
Network service unavailability and degradation affect performance of factory, and increase production failures	If mechanisms to detect, predict, and prevent network issues were available - then the I4.0 production would also improve.
Hazardous working environment for workers, and repetitive tasks	A centralised overview and control of a system (with 5G-enabled robots and other industry devices) could transform the whole supply chain. Could achieve cost reduction, increase operational efficiency, quality and sustainability, while providing flexibility for adapting to operational change.

Secure & Reliable Networks, Supply chain risks, Cloud & Virtualization security	5G architectures offer configurable network slices to address security, dynamic QoS requirements and reliability. Data sovereignty can be a critical issue for manufacturers, which can be addressed by on-premises edge computing or dedicated non-public networks deployed on factory campuses. The needs are ever-evolving, with the responsibility to ensure that the systems & technologies built protect users [10][11][12] by envisioning an environment in which decentralization, regulation and security implications play a role. **Constraints:** access to spectrum and cost
COSTS AND EFFICIENCY	
High costs of integrating with different networks High Customer Premises Equipment (CPE)/equipment cost for new 5G-regime	Through standardisation, economies of scale could be achieved, enabling: • cheaper/easier access to any network service • lower price for equipment **Other considerations:** • availability of industrial type 5G CPEs **Constraints:** Competition for the de-facto standard, "winner take all" dynamics, no economies of scale achieved for CPEs.
Too expensive/costly to invest in, and operate the needed infrastructure for each manufacturer	If co-investments were enabled, subscription models available, or purchase as-a-service was possible, then costs could be shared between many users/customers. If non-public network provider, or private network provider could take the role of providing private network-as-a-service and allow network to be adjusted to needs on demand, then a burden would be taken off the shoulders of manufacturers.

The four key design principles for I4.0 are presented in Table 2 [4], highlighting the necessity for advanced connectivity solutions to solve challenges in this vertical.

Table 2: Key ICT influencing I4.0 [4].

	Key ICT Enabling Technologies for I4.0			
I4.0 Design Principles	IoT / 5G	Cloud & Edge	AR & VR	ML/AI
Interconnection	Critical	Significant	Minor	Minor
Information Fusion	Critical	Critical	Significant	Significant
Human-Machine Collaboration	Critical	Significant	Critical	Significant
Flexible Decision Making	Critical	Critical	Minor	Critical

2.2. ACTOR ROLES

The actor roles in Table 3 have been chosen by the BVME-SG to explore business modelling in a 5G/B5G ecosystem for I4.0. The actor roles contribute with substantial activities and resources when creating a solution and value for the users and customers. Thus, their roles are necessary and complementary in order to implement or operate a solution.

Table 3: Actor roles in 5G/B5G ecosystems for I4.0 (see e.g., [7]).

Actor Roles	Description
Vertical Customer (i.e., the paying customer)	This role refers to the company/organisation (e.g., a factory) which buys the required communication and I4.0-specific application services, tailored to the needs of a specific use case of interest.
Service Aggregator (SA)	A Service Aggregator is an entity that curates and aggregates service offerings from multiple other providers (with potentially different roles) to offer complete value-added end-to-end solutions to enterprise customers (e.g., a factory/Vertical Service Providers). The Service Aggregator serves as a single point of contact for the vertical customer that consumes an end-to-end solution. For building and delivering the aggregated service, the Service Aggregator is supported by a System Integrator.
System Integrator (SI)	A System Integrator, a complementary and supportive role towards the SA role, brings together different subsystems into a unified system that functions seamlessly. The SI is highly involved in the setup phase of a solution, facilitating the design, integration, implementation, testing, and validation of the E2E solution. In the operational phase, the SI is responsible for the maintenance and scaling of the solution.
Digital Service Provider (DSP)	This role offers digital services, i.e., online application/information services that are consumed by the Vertical Customer. These digital services are integrated with communication, and potentially infrastructure services, offered by other roles in the value network. The DSP may not be the developer of the whole digital service, but parts of it may be contributed by application suppliers.
Application Supplier (AS)	This role focuses on the development of applications, using Application Programming Interfaces (APIs) to adapt software (SW) to the network etc., and these applications are usually specialized and specific to certain vertical sectors, e.g., I4.0, media, automotive. Contrary to the DSP, the application supplier does not participate in the provisioning phase of the solution.
5G Industrial Device Supplier	This role focuses on the supply of 5G equipment necessary for the provisioning of the complete vertical solution towards the vertical customer. This actor role is expected to often provide equipment via the Service Aggregator, rather than directly to the vertical customer. These devices may be user equipment, robots/cobots, AR/VR glasses, etc., that may be deployed on an industrial floor or utilized by the end-users (customers) for the consumption of vertical services.
Communication Service Provider (CSP)	This role focus on the delivery of communication services (voice, media, Internet, data network, IoT, etc.) relying on the network services offered by a Network Operator (see below). Usually, an actor that adopts the communication service provider role also adopts the network operator role.
Network Operator (NOP)	The Network Operator maintains and operates a network, offering network services (e.g. connectivity, value-added services), across part or all segments of the network (i.e., access, transport, core). The network service may be offered in the form of Network Slice-as-a-Service (NSaaS) or Network-as-a-Service (NaaS), e.g., public network integration with non-public network (PNI-NPN).
Data Centre Service Provider (DCSP)	This role offers cloud services, ranging from multi-purpose virtual machines (VMs) / containers to complete virtualised infrastructure management solutions, over virtualised / physical infrastructure that includes computational, storage, networking or IoT resources.
Private Network Operator	This role operates a private network, local access/radio. Can bundle network and other communication services. Can be realized in different ways and may substitute a NOP in an ecosystem configuration or be seen as a sub-role of the NOP [13] (i.e., not an independent role in e.g., Figure 2)

2.3. 5G/B5G ECOSYSTEMS

Figure 2 shows a high-level overview of the ecosystem that brings the actor roles discussed in the previous section together. For each actor role, an overview of the service / product offering is highlighted to aid the understanding of inter-role transactions within the ecosystem. Two suggested versions are shown for illustrative purposes (noting that others are possible): Figure 2(a) representing the set-up phase that covers the design and configuration of the E2E solution; Figure 2(b) represents the scenario where the system is in operation, allowing some actors to take on a more minor role (for inspiration, see [14]). In the latter figure, some actor roles (e.g., the SI) have been faded out to represent the idea that their active role in Figure 2(a) becomes less so in the operational phase. In the operational phase, the SI may need to stay somewhat active for support, maintenance, updates, etc. As can be seen, the ecosystem maps are useful tools to explore inter-role relationships and can be used to map where specific actor roles contribute to the ecosystem.

Figure 3, shows an example of specific actors that could potentially take on the actor roles highlighted above. The specific actors are suggested to the best of knowledge of this white paper's authors who take full responsibility for any misunderstandings or errors. The use of specific actors is helpful to capture how one actor can have several roles. The position of actors in the ecosystem can vary, particularly as the market matures, and, due to the intertwined nature of the ecosystem, such variations in the position of one actor impact the costs and value propositions of others in the ecosystem. We emphasize that an actor assessing business opportunities in the emerging market should not be limited by our examples and keep an open mind to how this could play out. This topic is elaborated in Section 2.5, while additional details are provided in Section 3.2.

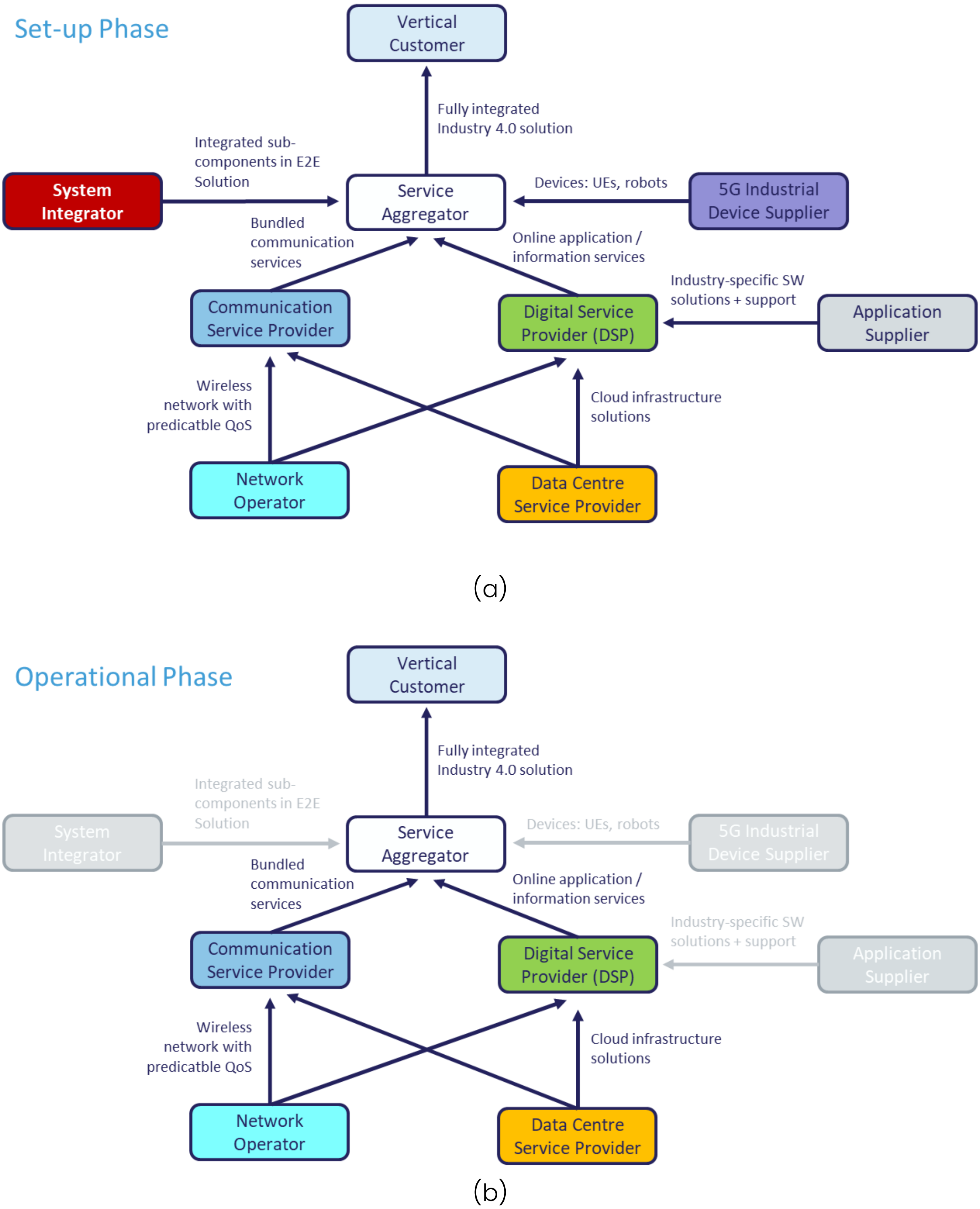

Figure 2: *Schematic of example ecosystem configuration showing* an overview of the services / products offered as part of inter-role transactions. Two versions are shown for illustrative purposes (noting that others are possible): a) representing the set-up phase, and b) representing the operational scenario. *The colours are used to denote the different actor roles and are used consistently to identify the same actor roles in all later figures.*

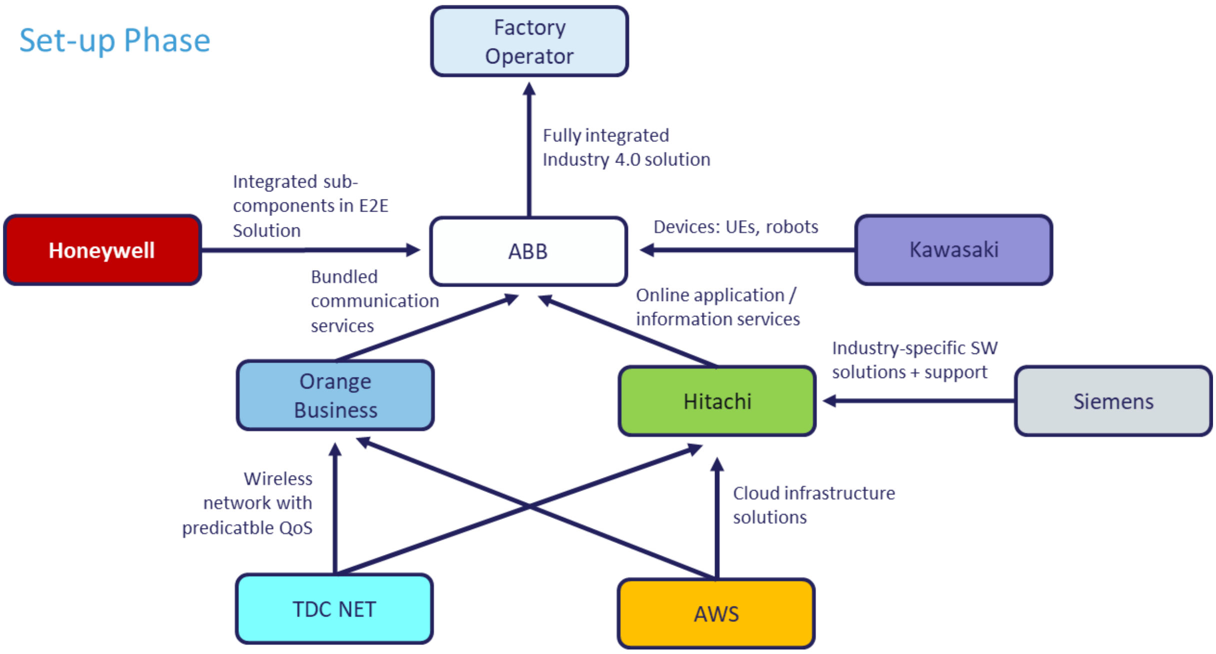

Figure 3: Schematic of example ecosystem configuration, showing specific actors who could take on actor roles.

2.4. ACTOR ROLES: BUSINESS MODELS

In Table 4 we suggest that each actor role has an archetype business model, which can be described using key activities in a business model canvas [15][3]. The business model activities that are specific, and differentiate one actor role from another, are marked with green text. These activities are at the core of an ecosystem and are combined to enable the delivery of the total value proposition to the vertical customer.

All actor roles contribute to delivering a total solution, they are dependent on what others are contributing, and each of the actor roles must be economically sustainable to make the whole ecosystem sustainable. This raises the question of which actor roles are essential for the overall ecosystem and must therefore be filled by some actor. Table 4 allows actors to understand other actor roles and explore opportunities of moving into those other roles. Any such movement risks challenging the fine-tuned competitive balance within the ecosystem.

In Section 3, more details are discussed on the costs and activities that an actor must take on in a new actor role to capture some revenue streams in this new role. We identify how synergy effects can be achieved from existing cost structures, customer base and interfaces, expertise, etc. This is also the foundation for the negotiation that takes place between actor roles and actors in an ecosystem in its early phases (or at any later stage when changes occur in the roles that actors assume).

Table 4 : Actor roles and description of the key attributes of their business models.

Actor roles /Business model canvas	Value Proposition	Customer Segments and Relationships	Key Resources	Key Activities	Cost Structure	Revenue Streams
Service Aggregator	Aggregates service providers in E2E solution; risk off-loading, one point of failure; share economies of scale with customers	**Factory** Key Account Manager (KAM) role for sale; digital interfaces in KAM operation, support, billing;	Domain specific insight; Large customer volume to handle risk and economy of scale	Handle key sub suppliers; portfolio and risk manage-ment; support;	OPEX flow for services aggregate; Human resources in support;	Start payment. Yearly fee. E2E solution as a service
System Integrator	Integration of sub-components into seamless E2E solution in set-up phase; consultancy;	**Factory, System Aggregator** Consulting and tech expertise; KAM role for sale.	Technology and integration experts;	Sell; integrate solution; handle key componen t suppliers;	OPEX heavy: Human resources. System licenses.	Per project; per hour
Digital Service Provider	Bundle network and compute services with Factory smartness/ application; domain specific expertise;	**Integrator, Factory, Aggregator,** Sale is KAM and digital; Operation digital;	Domain specific insight; Developer expertise; Reselling.	Adjust services to needs and resell as standard service;	OPEX flow purchasing services, to resell. Human resources;	Yearly fee
Application Provider	Factory smartness/ application; application/SW specific value;	**DSP** Sale, KAM and digital; Developer portals;	Domain specific insight; SW program-mers; IPR;	Design application s; code; support;	OPEX heavy in design = CAPEX; economies of scale for customer volume	Licenses. Yearly fee
5G Industrial Device provider	Easy to use, virtualized, flexible devices; device specific value;	**DSP** Sale, KAM and digital; Operation digital;	Domain specific insight; HW developers;	Design; plan production; logistics;	CAPEX costs manufacturi ng, economies. of scale for device volume	Per device. Leasing fee
Communication Service Provider	Bundle wireless network services with comm. services, UE leasing. Standardized and predictable services.	**Aggregator,** Composed solutions "as a Service"; Digital sales; Developer portals;	Large customer base; Combined service operation expertise;	Plan, implement and operate standard services; Resell.	OPEX - purchasing services, bundle and resell.	Yearly fee

Actor roles /Business model canvas	Value Proposition	Customer Segments and Relationships	Key Resources	Key Activities	Cost Structure	Revenue Streams
Network Operator	Public wireless network with predictable QoS and mobility, energy efficient. Interconnection	DSP, CSP, Aggregator Sale, KAM and digital; Developer portals; Operation digital;	Network operation expertise; CAPEX - financial resources;	Design; implement; operate; sell; support; allocation of CAPEX	CAPEX heavy; 5G equipment; economies of scale.	Yearly fee
Data Center Service Provider	Efficient hosting of application, low latency, energy efficient. Transport network	DSP Sale, KAM and digital; Developer portals; Operation digital;	Data centre operation expertise; CAPEX - financial resources;	Design; implement; operate; sell; support; allocation of CAPEX	CAPEX heavy; servers; economies of scale.	Yearly fee
Private network operator	Private wireless network. Flexible/mobile with predictable QoS. Sharing of investment burden. Public network integration.	Factory, Aggregator, DSP Sale, KAM and digital; Developer portals; Operation digital;	Network operation expertise;	Design; implement; operate; sell; support;	CAPEX heavy; Portfolio of customers /network —> economies of scale	Yearly fee

2.5. ACTOR ROLES: ECOSYSTEM POTENTIALS

The intention of this section is to analyse how different actors occupying specific actor roles can move into new actor roles or broaden their market reach through taking on additional actor roles. The outputs of this analysis are summarised in Table 5, while observations derived from this analysis are presented later in this section.

Outlining the business models for all relevant actor roles in the I4.0 ecosystem (as presented previously in Table 4 in Section 2.3) is necessary as a first step to enabling this analysis by helping to define an initial, generalised ecosystem configuration, as shown schematically in Figure 2. Following from this, it is informative to consider specific actors that can take on the various actor roles within the ecosystem. In Table 5, we suggest a potential mapping between some exemplary companies and the proposed actor roles, with the intent to ease the understanding of the framework we propose. The specific actors are suggested to the best of the knowledge of this white paper's authors who take full responsibility for any misunderstandings or errors.

Table 5: Actor roles and example actors[1] - indicating existing positions in ecosystem, and potential for moving into other actor roles.

Actor roles / Examples	Factory	ABB	Honeywell	Hitachi	Siemens	Kawasaki	Orange	TDCnet	AWS	Ericsson
Vertical Customer	Green	Red	Red	Red	Red	Red	Red	Red	Red	Red
Service Aggregator	Blue	Green	Blue	Blue	Green	Blue	Green	Red	Red	Red
System Integrator	Blue	Green	Green	Blue	Green	Blue	Blue	Blue	Blue	Red
Digital Service Provider	Red	Blue	Blue	Green	Blue	Blue	Blue	Blue	Blue	Blue
Application Supplier	Red	Green	Red	Green	Green	Blue	Red	Red	Red	Red
5G Industrial Device Supplier	Red	Green	Red	Green	Green	Green	Red	Red	Red	Red
Comm. Service Provider	Red	Red	Red	Red	Red	Red	Green	Blue	Red	Red
Network Operator	Red	Red	Red	Red	Red	Red	Green	Green	Blue	Red
Data Centre Service Provider	Red	Red	Red	Red	Red	Red	Green	Blue	Green	Blue
Private Network Operator	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Green

Green	The main incumbent actor role for the example actor - our suggestion
Blue	An actor role that an example actor could take
Red	Not relevant actor role in this analysis

The diagonal in Table 5 is highlighted with black borders to represent the suggested initial ecosystem mapping, the configuration of which was shown in Figure 3 with the exemplary company names. As actors explore the potential of the ecosystem and take on additional roles or change position in the ecosystem, Figure 3 can be updated to reflect any changes.

1 Example companies web-sites in table heading order: global.abb, honeywell.com, hitachi.com, siemens.com, kawasaki.com, orange.com, TDCnet.com, aws.amazon.com, ericsson.com

The blue cells in Table 5 help to visualise these possible ecosystem reconfigurations, as these cells show the potential actor roles that the listed actors can possibly take on. The use of such visualisation methods is encouraged as they allow actors to continually assess dynamic ecosystems and how best to react to changes. Through this analysis, various considerations arose for the different actor roles due to changing competitive forces and need for alignment in the ecosystem. The following describes these observations:

Vertical Customer, e.g., the factory: the factory can take roles as SI and SA. It may itself be the only one willing to carry the risk for the E2E functioning of a solution.

Service Aggregator, e.g., ABB: the SA can take roles as SI, DSP, Application Supplier and 5G Industrial Device Provider. ABB seems to have these roles already, except the emerging actor role, DSP. The SA may also take on the SI role, as the same expertise is needed, and thus, the OPEX cost structure is the same. Also, to take on the SI role may ensure new customers to the SA, building a large enough portfolio to handle risk. The combined domain-specific competence of a SI and SA allows such an actor to move into the actor roles of Application Supplier and 5G Industrial Device Supplier. However, the key resources, activities and cost structure are different in these latter roles, e.g., more CAPEX heavy. To step into these roles is thus more challenging. Still, companies like e.g., Siemens and ABB seem capable of covering all these roles.

System Integrator, e.g., Honeywell: the SI can take roles as SA and DSP. Its cost structure as SI is mainly OPEX and human labour, which can be reused in e.g., support. Any expansion to cover the SA role does not imply fundamental changes in cost structure, this additional actor role only expands the OPEX responsibility. The synergy increases with a larger volume of customers, both regarding expertise and risk management in customer portfolio.

Digital Service Provider, e.g., Hitachi: the DSP is a recently suggested actor role adjusting applications to the specifics of compute and connectivity resources. This is because the role is OPEX heavy requiring expertise in configuration of E2E I4.0 solutions. Provided such configuration expertise resides in the company; this means that the starting point for this role can be from any of the other actor roles. For example, even CAPEX heavy actor roles, which are used to configuring and adjusting their own operations, can have a strong starting point for this role.

Application Supplier, e.g., Siemens: the Application Supplier can take actor roles as SI, SA, DSP and 5G Industrial Device Provider. Siemens and ABB have these roles already, maybe also the DSP. We assume it is more challenging to move to the 5G Industrial Device Supplier role as an Application Supplier and that the path is more likely the opposite way around (i.e., an actor starts with CAPEX heavy manufacturing and moves into applications and integration).

5G Industrial Device Supplier, e.g., Kawasaki: the 5G Industrial Device Supplier can take roles as SI, SA, DSP and Application Provider. Kawasaki seems to be offering more generic devices for I4.0. Thus, to address market needs, actors in this role can offer domain-specific applications for more generic devices for I4.0.

Communication Service Provider, e.g., Orange: the CSP is often already integrated with a NOP. However, we think that an independent CSP would not take the step into the CAPEX heavy NOP or DCSP actor roles. It could however purchase, bundle and resell services from these actor roles. We suggest Orange as an example in this actor role, which is also filling the role of NOP.

Network Operator, e.g., TDC NET: The NOP is often already integrated with the CSP and may find reasons to take on such roles due to synergy effects. The actor example, TDC NET, is however an instance of the opposite, the NOP is split and made independent of the CSP. Even though these operate in the same domain (telecommunication), the NOP and CSP have different value propositions, key resources, key activities, and cost structures. The NOP has more similarities with the business model canvas for the DCSP and could move into this actor role. Orange, which seems to be both a CSP and NOP, has already substantial activity in the role as a DCSP, with its subsidiary Orange Business. Furthermore, we suggest that independent NOPs can find the DSP actor role more interesting than the CSP role, establishing in domains beyond the traditional telecommunication consumer market.

Data Centre Service Provider, e.g., Amazon Web Services (AWS): The DCSP has a CAPEX heavy cost structure, and it may be interesting to step into the similar NOP roles to further achieve economies of scale. Other than that, we assume that the DCSP is interested in being a SA and DSP. These are roles that may become more important as E2E solutions are realized. The argument could be to fill an actor role with a different business model, however, to build on the experience with hosting developers may provide momentum to become a large actor across many different industries.

Private Network Provider, e.g., Ericsson: Providers of indoor cabled network and Wi-Fi have been a reality for many years, however, the private networks using 5G is a fairly new concept [13]. We suggest that most of the actor roles can enter the Private Network Provider role in an I4.0 use case; it is complementary to their offerings. However, we suggest that it is less beneficial for actors that cannot deliver on the expectations for investment sharing and subsequently lower prices. In addition, the ability to develop or access suitable competencies in 5G/B5G network provisioning and operation is also a major consideration, likely to constrain actors from entering this role.

General Observations

Our analysis in Table 5 indicates two clusters of actor roles, around the DSP and NOP. These clusters to a large degree overlap with what has been denoted as the 5G vertical ecosystem and 5G provisioning ecosystem [7]. In general, we see that actors already are positioning in adjacent roles within these ecosystems, however, the jump from one cluster / ecosystem to the other is rarer.

In line with this, we do not suggest that CSPs, NOPs or DCSPs can easily move into the actor roles of SI, AS and 5G Industrial Device Supplier. Both the cost structure and expertise needed are very different. However, we suggest that the actor roles of SA and DSP are an opportunity for most of those occupying the CSP, NOP or DCSP roles, as they are respectively transactional and involve bundling of other resources; thus, these actor roles are presumably less challenging to enter, even though they have a different cost structure.

We also consider that the DSP actor role is recently identified and may be relevant for several of the actors. In addition, it seems easier to move from being a supplier of devices to being a supplier of applications, than the other way around.

3. STRATEGIC 5G/B5G ECOSYSTEM BUSINESS MODELLING FOR I4.0

When a for-profit actor operates in a market with ecosystem characteristics, whether emerging or in more mature phases, and considers new business opportunities, questions arise about business models, positions, competition and complementarity. A set of such questions can be found in Table 6:.

To address these questions, the actor needs some key insights, which can be derived from appropriate analysis. In this white paper, we suggest some of this insight for the I4.0 example. The approach taken provides a foundation for analyses which could be done by other actors in the 5G/B5G ecosystems focused on the same or other verticals.

For example, the assessment in the preceding section has provided a starting point for such an analysis. It has outlined the problem to be solved, and that an ecosystem can best create value for the I4.0 stakeholders. It has also:

- Identified: The relevant actor roles in the 5G/B5G ecosystem for I4.0.
- Suggested: Some alternative ecosystem configurations.
- Suggested: The different business models of the actor roles.
- Suggested: The potential of an actor in one role, to move into other actor roles.

In Sections 3.1 to 3.4, we further address how answering key questions related to changes in ecosystem dynamics, such as those in Table 6:, can be supported by our analysis of the 5G/B5G ecosystem for I4.0.

It should be noted that all analyses are dependent on the data and assumptions they build upon. Such data refers to all input information used for the analysis, such as: actor roles in a specific ecosystem, actors taking on those roles, abilities of specific actors to provide various services or transition to different actor roles, etc. Thus, any player willing to perform such an analysis for its own commercial purposes has to qualify such data and properly adapt the framework proposed by this white paper. We also assume that a detailed application implies several iterations of data gathering and analyses.

In the following, we first touch upon if and how key questions can be addressed with the insight provided in Section 2. We offer some examples of more detailed analyses, which follow the theme of the previous section where I4.0 is used as an example.

Table 6: Example questions asked when actors are developing business models in 5G/B5G ecosystems.

- To enter a new role:
  - What do I gain if I enter a new actor role: impact on costs, new customer segments, different business model component, new revenues?
  - What are the risks involved: Business or financial risks?
  - What do I lose / why would I not go for the additional revenues (i.e., what is the opportunity cost)?
- Looking at the other actor roles, how can I increase the value of my own actor role?
- The new actor role DSP:
  - The DSP is a relatively new role, should I consider positioning for it?
  - If I took the DSP role, how would this affect the other actors in the ecosystem?
    - Tensions, blockers towards other actor roles and actors?
    - Would the ecosystem grow?
    - How could I decrease the risk in the DSP role?
    - How could I off-load risk to other actor roles?
- If I take on the actor role as DSP, should I:
  - integrate it with my other actor roles, or
  - should I keep them separate?
    - Benefits from integrating actor roles?
    - Benefits from independent actor roles, so that I am free to choose whichever partner?
- Are there synergy effects between actor roles?
  - Potential between network and data centre? If yes:
    - Transport (core) and data centre?
    - RAN and data centre?
- What is the bottleneck actor role in the 5G/B5G ecosystem?
- How does Interconnection play a role in the business models? Private and public network?
- Which business model activities or components could be moved between actor roles:
  - Risk taking
  - Logistics
  - Relationship with Factory customer – work with problem and solution design
  - How to share economies of scale with Factory customer
  - Support
- How will requirements on sustainability affect the business modelling in 5G ecosystems?
- What are potential "new, demanded services" for a network operator, bringing new growth (top-line revenues)? A question that network operators are eager to address.
- Can the I4.0 ecosystem, actor roles, and business models be reused for other industry verticals, e.g., the health sector?
- What are potential generic services cutting across different verticals?
- Are there learnings from business modelling in the 5G/B5G ecosystem, which are transferable to the 6G ecosystem?

3.1. EXPLORING STRATEGIC IMPLICATIONS OF CHANGES IN ECOSYSTEM DYNAMICS

As discussed above, ecosystems can be dynamic in terms of actor roles and the actors taking on those roles, where changes can be driven by policy, technology advancements, variability in business priorities, etc. The goal of this subsection is to provide examples of key strategic considerations that 1) arise due to the dynamic nature of the 5G/B5G ecosystem, and 2) can be assessed using the framework discussed earlier in this white paper.

Decisions based on applying the framework and assessing the resulting information can only be made by the companies carrying out the assessment and cannot be discussed here in a generalised manner. This is because of the necessity to consider the specifics of the companies involved in terms of business priorities, capabilities, relationships with others in the ecosystem, etc. The framework can, therefore, be viewed as a template for companies to analyse 5G/B5G ecosystem dynamics, which provides insights for those companies to act on as they see fit. The text below provides examples of important considerations arising due to changes in ecosystem configurations that can be explored as part of applying the framework and used in subsequent decision-making.

Impact of collaboration between actor roles: First, identifying actor roles, their potential business models and the components of those business models (e.g., seeTable 4) enable exploring different configurations for the entire ecosystem and each actor role. The key benefit of this approach is that this analysis is done for several actor roles simultaneously, and not only from one perspective. It reveals dependencies, synergies, advantageous sharing of actor roles and competitive opportunities. For one actor role, which is interested in focussing on one strength across many markets, the mapping of other actor roles and business models enables understanding of which ecosystem partners to mobilise to build and share a market. Sections 3.2.1 to 3.2.3 provide exemplary analyses.

Impact of entering a new role: As it is tempting to capture a larger share of ecosystem revenue streams, our analysis illustrates that this may come at the expense of new business model cost components e.g., more CAPEX, labour costs or higher risks. Also, in the ecosystem configuration, the relationship to other actor roles, which you are dependent on, must be considered. The overview of the business models of others helps assessing what their views may be, and stresses advantages or disadvantages of your moves. Section 3.2.3 provides exemplary analyses.

Synergy effects: When considering entering new actor roles, the outline of all the ecosystem business models quickly demonstrates potential synergy effects between roles. Example of synergy fields are heavy CAPEX and economies of scale, or vertical domain expertise. For instance, we see that network and cloud infrastructure share the same CAPEX-burden. The implication of taking advantage of synergy effects is the clustering of business model components which are similar (e.g., in the 5G provisioning ecosystem, network services and infrastructure may be divided into new actor roles by the underlying business model components, which again would introduce new ways to merge with the data-centre actor roles). In a technoeconomic analysis in Section 3.3, the different synergy effects emerging from business model components are further clarified.

Becoming a Digital Service Provider or Service Aggregator: It is suggested that the selling, integration, and delivery of solutions to I4.0 stakeholders may require a new role like a DSP or reinforcement of the SA. The roles can work more closely with the customer and have domain expertise. The SA can carry the risk for the functionality of the solution. The ecosystem configurations and the business models of the actor roles help in highlighting pros and cons of taking on such a role. For instance, it illustrates the revenues but also the cost that could be carried in this role. With increased revenues also comes the responsibility to ensure the quality of the service, and the obligation to manage the portfolio of all other providers[2].

In an ecosystem context this illustrates how offerings may not be sourced via an aggregation point with full responsibility. Instead, the different components would be delivered directly to the customer from interdependent ecosystem actor roles, and thus, decrease the burden on any one actor role. Or, the SA role could be more like an coordinator with no responsibility of the actual service delivery, only a mediator. Both revenues and costs could then remain with the other parties. Section 3.2 addresses questions related to the value of such roles in the ecosystem and if such a role could survive over the longer term.

Is there a bottleneck and/or platform actor role in the 5G/B5G ecosystem? The bottleneck or platform actor role in an ecosystem is an empirical question: easy to point at in a mature market but challenging to identify in early markets. Thus, the ambition to become a platform, or fear of others trying to become the bottleneck platform, often leads to competitive dynamics that delay or hinder market initiation: the different actors are not taking the risk to invest, when not knowing what they can get in return or how to get that return. Interfaces, the point of combining different services, are held to be the foundation of a platform leadership role. Also, the ability to achieve positive network effects via platform customers and providers in early phases, and by their persistent preferences in later phases may build a platform position. This information cannot be derived from all the actor roles' business models. However, those actor roles that handle CAPEX-heavy infrastructure and equipment where standards and specifications play a role are potential platform candidates, i.e., data centres, 5G network providers, and 5G industrial devices providers. Also, the aggregator role as a mediator between customers and other actor roles may become powerful, due to the attraction effects on others (i.e., their preferences). However, the aggregator role often includes domain specific expertise; actors with platform ambitions could consider a more

2 As mentioned in the introduction, Step 4 of the process (see Figure 1) is included to evaluate the different price and revenue models, helping to develop precise business plans and understand associated risks. As discussed, this step is not focused on in this white paper, as such an analysis would be necessarily specific to the companies involved and difficult to generalise here.

withdrawn position to scale globally. Thus, our business model description for I4.0 in Section 2 may also shed some light on bottlenecks and platforms.

5G/B5G ecosystem business modelling and sustainability expectations: Sustainability introduces a new cross-cutting layer to the topics presented in Section 2 covering environmental, social and economic sustainability perspectives. Considering different business models and ecosystem configurations need to integrate circular economy principles, this will impact the actor roles of the ecosystem, their value creation and cost structure, and thus, their business models. In turn, there may be new business opportunities from sustainability. Benefits and costs for the business models of the actor roles must be carefully considered – expanding the traditional business aspects into environmental, social and economic elements. Moreover, a company needs to report on its sustainability efforts and that impacts how to make business decisions, e.g., the transparency in ecosystem configurations and business relationships.

Applicability for other sectors, e.g., health: When considering the applicability of the proposed methodology to other vertical sectors, it is essential to consider the specifics of each of them separately, bringing in domain-specific knowledge that will help to identify if changes to the ecosystem actor roles proposed above and/or changes to the ecosystem configuration are needed. For example, in the health sector, technical and regulatory challenges, as well as the scalability and adaptability to future technological advancements of a system, raise major challenges.

One of the major challenges to consider in this space is that multiple health systems must seamlessly share data across platforms, demanding robust integration of solutions that comply with domain specific standards and regulations. This requires secure storage, secure transmission methods and robust networks, therefore developing cloud infrastructure tailored to the security needs of health records is crucial. Since healthcare systems often demand real-time data sharing, particularly for tele-medicine, monitoring health data, or robotic surgeries, reliable, low-latency networks are critical. This data sharing also needs to adhere to patient privacy laws, medical device regulations, and ethical standards in healthcare delivery.

Like the I4.0 challenges listed in Table 1, the health sector has challenges that can be partially or fully addressed by advanced connectivity solutions. The ecosystems that provide value to this ever-evolving vertical must develop a business model similar to that presented above for I4.0, while considering how critical data privacy challenges could be addressed to ensure trust and usability, while also considering the actor roles that will be able to ensure delivery of related services.

3.2. ECOSYSTEM DEPENDENCY AND TENSION

In Section 2, we describe some archetype business models for a set of actor roles in Table 4 and how actors are positioned to move between actor roles. Here, we suggest that in an emerging ecosystem this initial description is only the starting point that will evolve as the ecosystem matures. The actor roles, driven by prominent actors, have the scope of exploring and negotiating how to position, which key activities to carry out, what to trust and how to mobilize others to contribute. In [3] this negotiation was illustrated as in Figure 4:. When one actor role or actor changes a key activity, it affects its position relative to the other actor roles in the ecosystem.

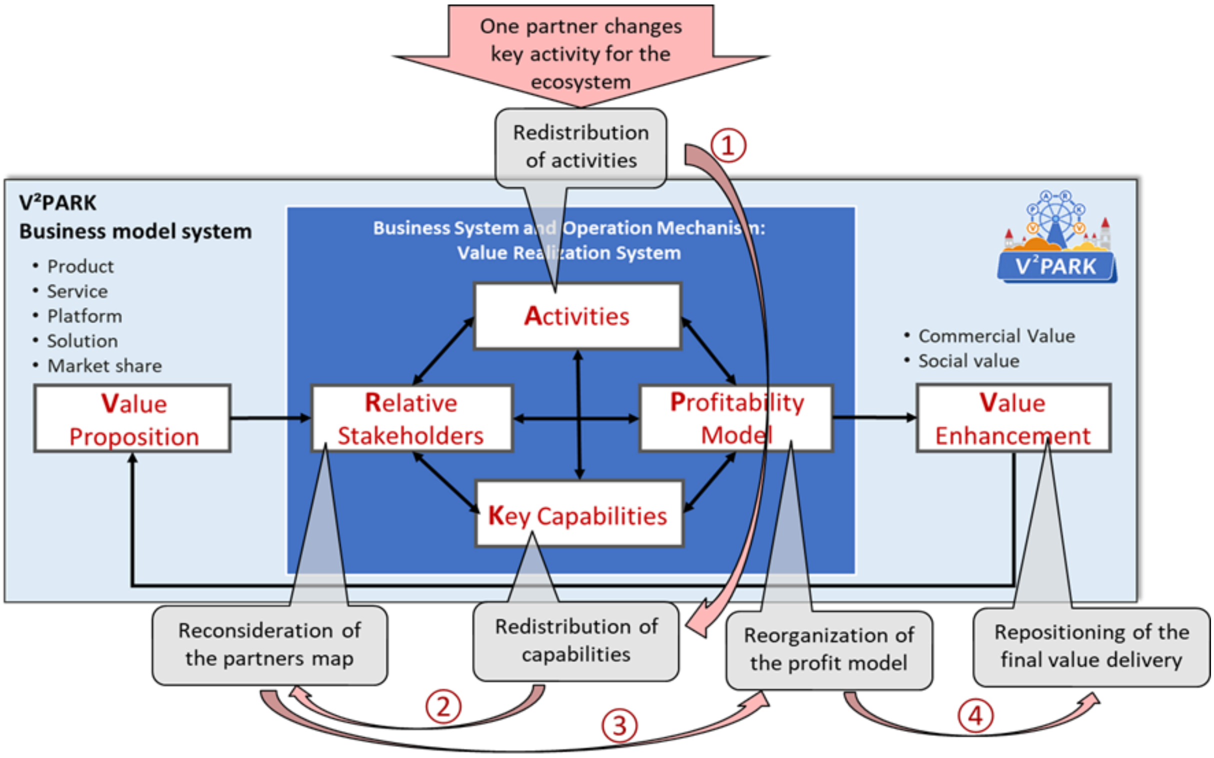

Figure 4: Example of how a change in actor key activity affects a business ecosystem [3].

Below, we provide guidance on how to assess the impact of such changes in the ecosystem using three scenarios:

1) What happens to existing business models when one actor takes on more actor roles?
2) In a situation where one actor has options on what actor roles to take on, how comparisons can be made on the effects to its baseline business model?
3) What are the implications to an actor's baseline business model when another actor takes on additional actor roles?

Figure 5 is the starting point for this discussion, where the business model activities for all actor roles have the status as suggested. For instance, the business model has a specific cost structure and key resources. In this baseline case, everything is in balance within the ecosystem. The ecosystem is slightly simplified, e.g., we bypass the CSP and let the NOP represent a "telecommunication operator" and the associated business model components.

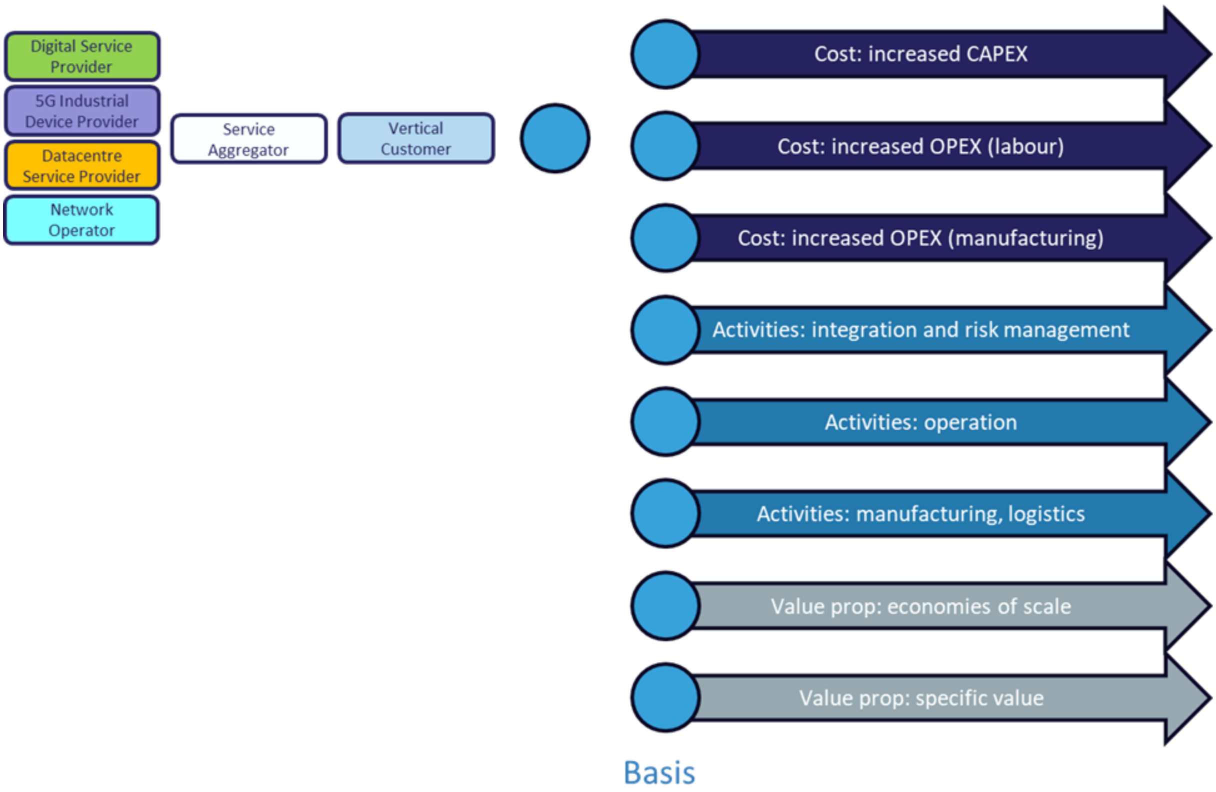

Figure 5: The basic starting point for some key actor roles, and some key business model component (aggregated). For actors, considering entering new actor roles, it illustrates where they start.

3.2.1. SCENARIO 1: ONE ACTOR IS TAKING ON OTHER ACTOR ROLES IN THE ECOSYSTEM

In the first scenario we give an example of a ***NOP X*** that decides to position itself in more actor roles, e.g., the DSP and DCSP. In Figure 6, we see that by moving into these actor roles, the business model for NOP X changes. The business model components most affected are included in this example using yellow circles.

For the NOP X moving into new roles, its value proposition moves more in the direction of delivering domain specific value to customers, however, the economies of scale proposition remain the same. It takes on even more CAPEX, which reinforces its economies of scale position. However, it needs more and different types of human resources and, therefore, its operation changes and OPEX increases. Finally, the increased activities with integration of the total solution increase risk exposure and make the risk management more complex. These changes in the baseline business model are represented by the yellow circles in Figure 6.

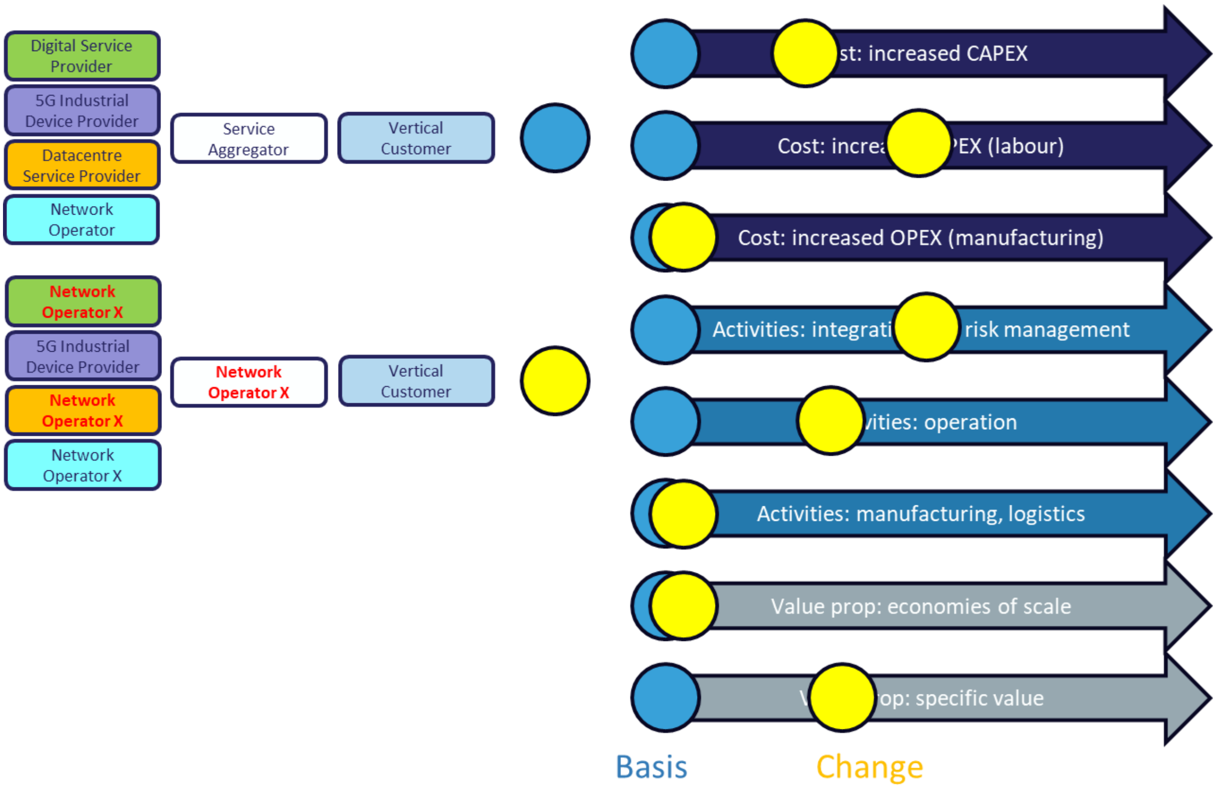

Figure 6: Illustration of the changes in business model components the actor NOP X must expect if taking on other actor roles. The new roles NOP X takes are marked using red text on the left hand-side.

Another example in this scenario is when a ***SA Y*** takes on several roles. The SA Y takes on the roles as DSP and NOP. In Figure 7, we have added this on top of the first example in Figure 6. First, for this actor the CAPEX increases due to the CAPEX requirements of being a NOP. Also, operation activities increase as it carries out the operation of network itself, i.e., not only resell the services of other actor roles. It must probably also onboard some other types of competencies, e.g., developer competence as a DSP. The SA Y already takes a lot of risk, so this does not change. However, the value proposition for economies of scale increases. As a SA, it is important to handle risk with a large portfolio of customers; with a NOP's high CAPEX, the value created from and need for network economies of scale also increases.

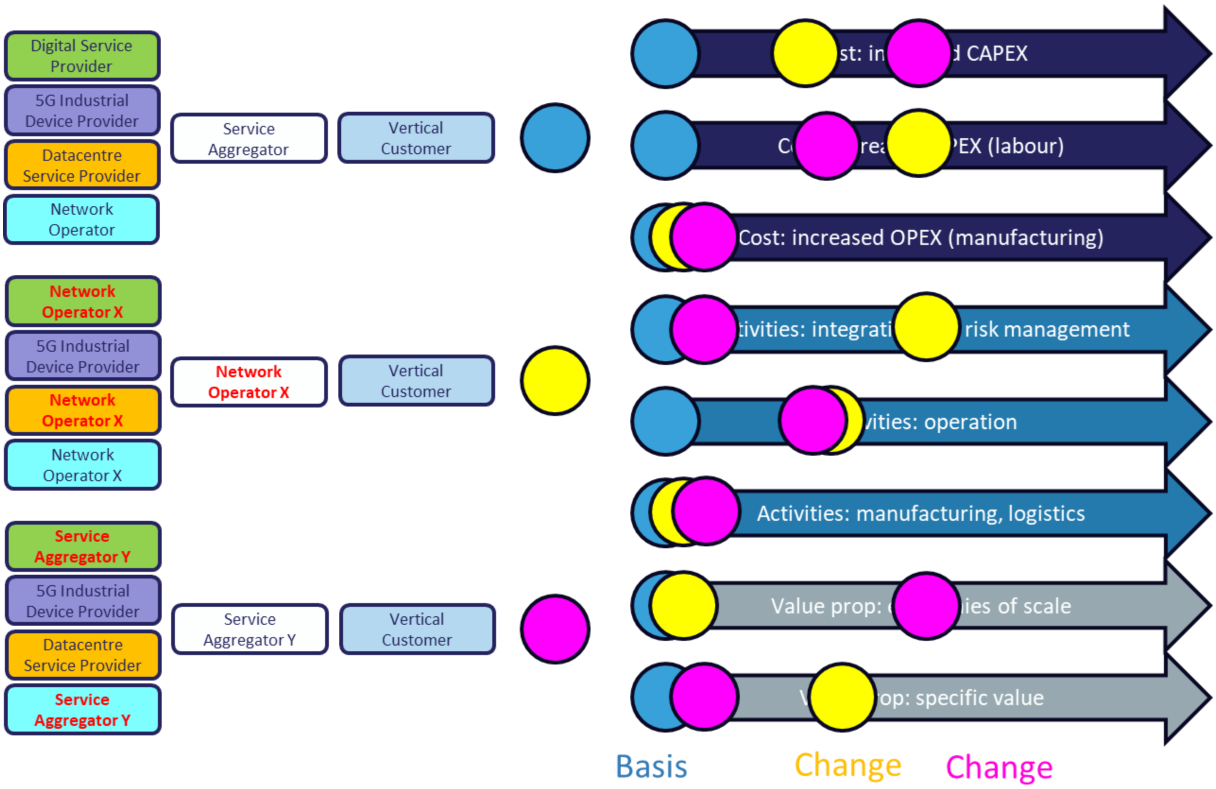

Figure 7: Illustration of the changes in business model components the actor SA Y must expect if taking on other actor roles. The new roles SA Y takes are marked in red text on the left hand-side.

3.2.2. SCENARIO 2: ONE ACTOR COMPARES POSITIONING IN SEVERAL ACTOR ROLES

In this scenario, the *NOP X* compares the effects on its business model when positioning in one or more new actor roles (see Figure 8:). Here, we see that when the NOP X only takes on the actor role of SA, its business model components, which are labour intensive, increase, as does OPEX and risk management. It also adds domain-specific value to its value proposition. The graphical representation of the two strategies gives the actor the opportunity to consider its options by comparing two moves in the ecosystem.

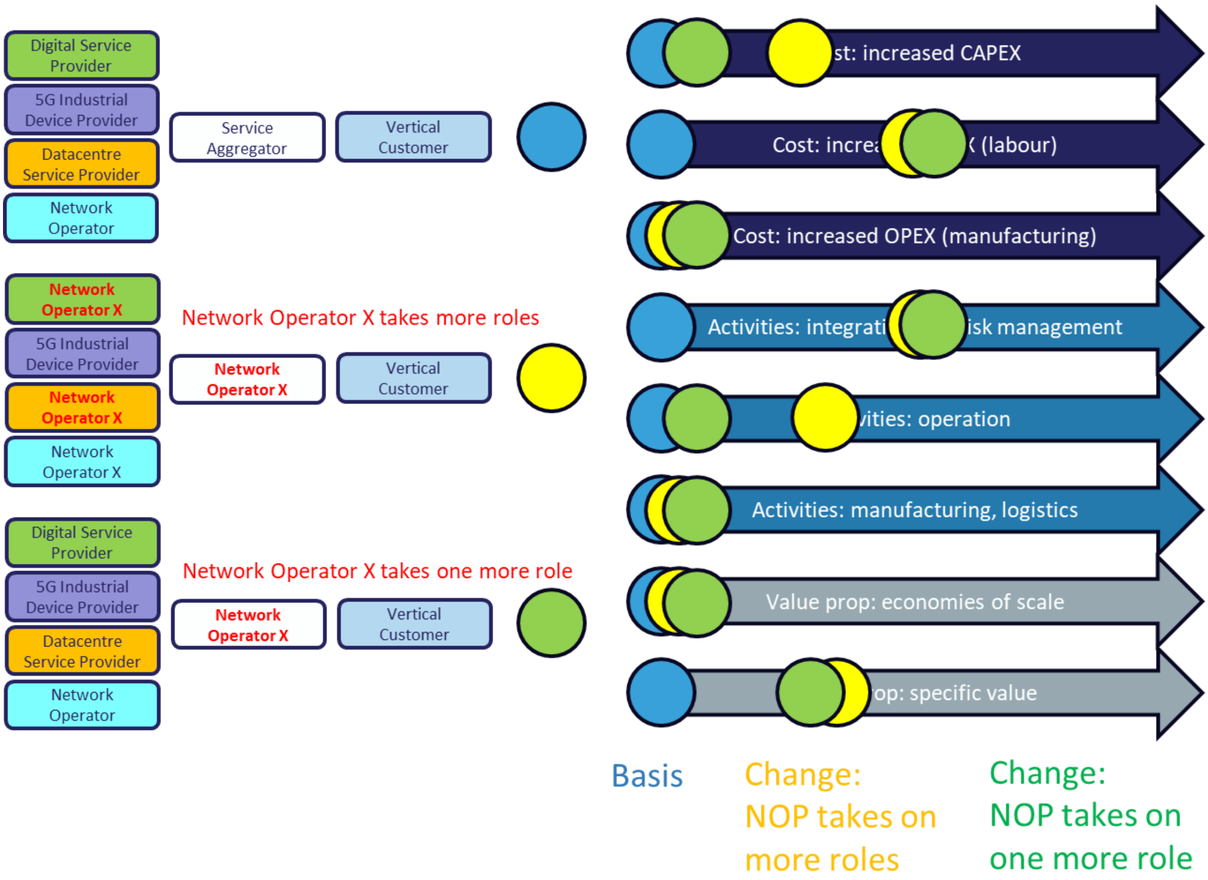

Figure 8: Illustration of how business model activities may change if one actor takes one or more other actor roles.

3.2.3. SCENARIO 3: ONE ACTOR TAKES ON MORE ACTIVITIES IN THE BUSINESS MODEL

In this scenario, we do not discuss the actor moving into other actor roles. Instead, we illustrate the impact when actor roles change their business models, which in turn affect the business models of other actor roles. For instance, if the NOP actor role starts taking on more support activities for the whole ecosystem, other actor roles change their business models accordingly – see Figure 9. The revenue and cost effects have to be considered by all parties. There may be underlying synergies and thus, good reasons for all parties to move in such a direction. However, competitive forces may drive actors more unwillingly into new balances. Thus, the effects on the sustainability of the whole ecosystem must be considered when such moves are explored.

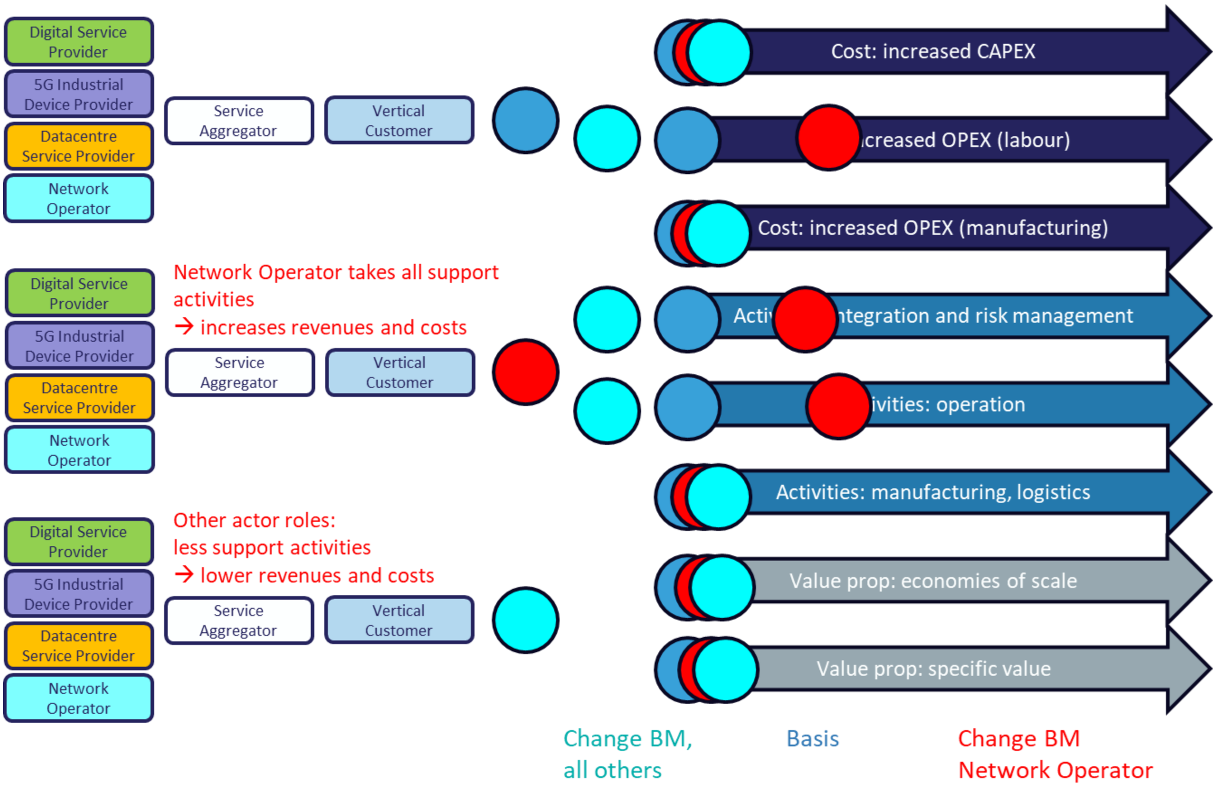

Figure 9: Illustration of how business model (BM) components may change if e.g., a NOP takes on more activities from other actor roles, and how business model components change for other actor roles.

3.3. A TECHNOECONOMIC VIEW OF ECOSYSTEM FORMULATIONS

To build on the discussion from the previous subsection, it is important to explore a more detailed techno-economic analysis of the 5G/B5G domain to derive further insights on cost structures and how those costs can be distributed and recouped across the ecosystem.

To elaborate, the emerging disaggregated 5G infrastructure implies new ways of operating networks, but also new business models for actor roles shifting from value chains to ecosystems. The economic viability and sustainability of one ecosystem formulation, however, depends on whether the formulation is sustainable for all actor roles. It is the cost structures per actor role and actor that drive individual economic sustainability. Thus, this section further details relevant activities and cost structures of the roles/ actors identified and discussed in Sections 2 and 3. Moreover, the cost structures per roles/actors are associated with 5G technology segment/ layer/ equipment/ activity that needs to be purchased/ developed, deployed and operated.

From a technical perspective, 5G/B5G networks comprise network functions that “can be implemented either as a network element on a dedicated HW, as a SW instance running on a dedicated HW, or as a virtualized function instantiated on an appropriate platform, e.g. on a cloud infrastructure" [16]. Already from 3GPP Rel.15, the technical approach is to have an ***underlying infrastructure layer***, serving as baseline resource layer, where higher communication network layers are implemented on top. This trend is expected to be reinforced and consolidated by open radio access network (O-RAN) and 6G networks.

At the ***underlying network infrastructure layer***, converged optical and wireless transport segments serve as network infrastructure resources enabling Radio Access Network (RAN) backhauling and fronthauling. Following large-scale network practices, traffic is hierarchically aggregated at various levels as it is transported from the access to core network segments.

At the ***underlying compute infrastructure layer***, compute resources enable processing of applications and network functions. The compute resources reside at various network segments. They can be distributed along the cloud-edge continuum (close to the first or second aggregation level sites) or deployed centrally (as central clouds deployed close to or hosting the 5G core network functions).

Over this disaggregated infrastructure layer, alternative deployments can be realized by 5G network functions and applications [7], reflecting the responsibility of various 5G ecosystem actor roles. Based on the 3GPP standard [16], which defines various service provisioning layers, the 5GPPP Architecture Working Group [7] has provided a mapping between the 5G technology layers and the 5G service provisioning business activities and processes.

As described in detail in Section 2, with a combined business and technology perspective, we distinguish between actor roles from the lower to higher service provisioning layers. The DCSPs (including the Virtualization Infrastructure Service Provider(s) (VISPs)) and the NOPs perform activities related to acquiring/ owning compute and network equipment and deploying the compute and network infrastructure. The NOP role implies operating the transport network infrastructure as well as a 5G network infrastructure including RAN, Edge, 5G core network (CN) segments or parts of it (i.e., only the RAN, only the 5GCN etc.). This role can in turn be split between actor roles, especially between the provisioning of transport and 5G/B5G network elements/ resources. It can also be extended to operating virtual resources acquired by other Infrastructure Providers. Both NOPs and DCSPs offer virtualized resources to the next service provisioning layer.

In the analysis in Section 2, the next service provisioning layer includes the CSP and the DSP. The CSP and DSP obtain/ lease resources and services from the NOPs and DCSPs. Next, they combine them to provide communication and application services to the SA. Therefore, the CSP and DSP activities include the configuration and operation of the underlying compute and network elements. Their activities also include the deployment and provisioning of network and application services to SAs (completely or partly). Finally, the activities of the SA role include the bundling of services, and the operation and monitoring of the application services.

A general mapping between the network and application assets and the underlying technology purchase, deployment and operation costs for each of the 5G/B5G ecosystem roles is illustrated in the Figure 10.

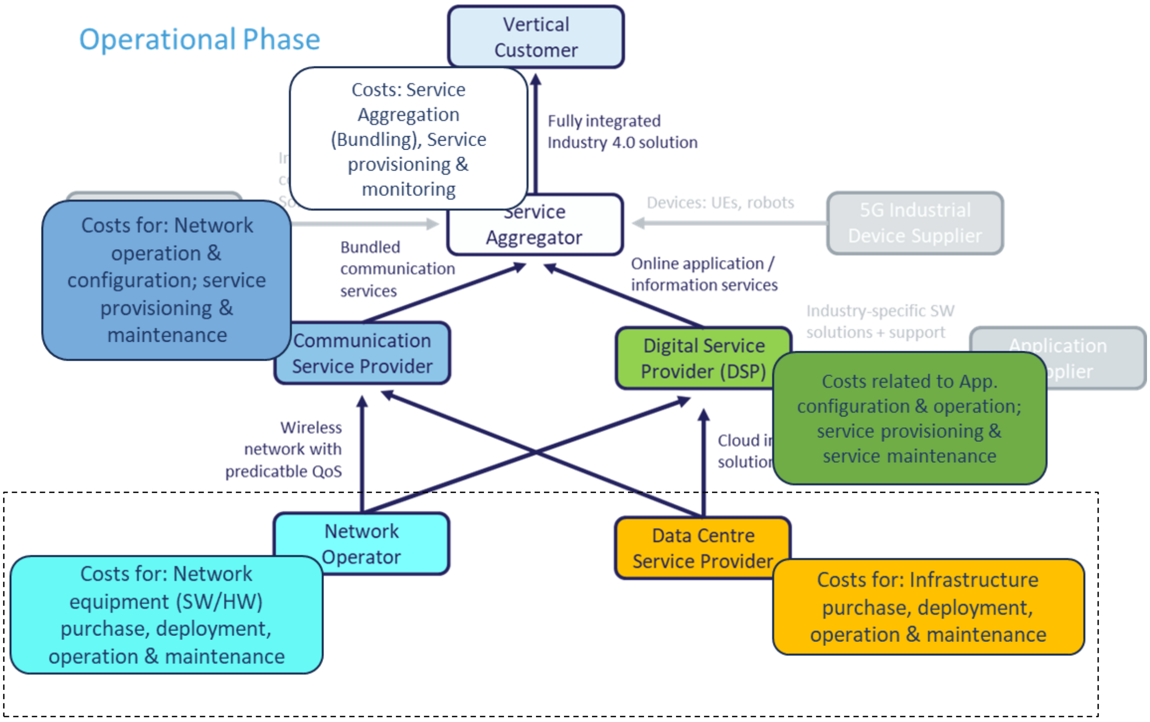

Figure 10: Overview of 5G Service Provisioning roles and generic cost structure per role.

So far, a typical approach to technoeconomic analysis in the 5G domain is to assess the total CAPEX/ OPEX/ total cost of ownership (TCO) of a complete 5G network deployment (e.g., as summarised in [17]). However, as we move from value chains to ecosystems, the activities and costs related to technology equipment purchase, deployment, operation, maintenance and (on top) service provisioning is split/shared between actor roles. The costs can still be undertaken by one single actor or by multiple actors - the difference between 5G/B5G value chains and 5G/B5G ecosystems. At the same time, 5G/B5G networks come along with a variety of deployment options when targeting a specific deployment case/ environment/ vertical/ etc. Therefore, it is no longer sufficient assessing only the total network TCO for a deployment option in a wider ecosystem as this hides the costs and benefits for all the involved actors. Instead, technoeconomic studies must be extended with (1) a structured view of the costs for different actor roles operating within the 5G/B5G provisioning ecosystem, and (2) a careful modelling and deep understanding on the various network deployment options (at technology level) and the subsequent incurring costs for each actor role. This approach can enable actors to identify hidden variances in cost structures and in turn increase their ability to exploit economies of scale and scope or identify specific sustainable ecosystem formulations.

3.3.1. TECHNO-ECONOMIC ANALYSIS USED FOR 5G/B5G ECOSYSTEM VALIDATION

Several 5G PPP EU-funded projects have proposed technoeconomic analysis methods that on a smaller scale aim to assess the factors with significant impact on cost, and in turn extract implementation guidelines for network roll-out at large scale (e.g., [18][19][20]). These studies assessed the total TCO of the network deployment and service provisioning even though the 5G network deployments reflect a variability of options targeting versatile vertical/ vertical environments and scales. It would be beneficial to combine these methods with the 5G/B5G ecosystems perspective. The technoeconomic assessment of 5G/B5G network deployments could be kept as such deployments scale from vertical sites to public networks, while performing segmented technoeconomic studies incorporating the more actor-specific considerations, i.e., analysing more focused cost-structures.

The methodology would include the steps identified for the calculation of the complete solution dimensioning (irrespective of the actors' activities) and TCO, as listed below:

- Identification of vertical site coverage area and modelling of RAN based on the radio environment specifics.
- Identification of service demand and forecasts over a targeted period.
- Definition of a layered deployment blueprint – reflecting the alternative technologies/ technical options at corresponding segments and layers (i.e., Infrastructure, Virtualised Infrastructure Services, Network Services).
- Dimensioning of deployment, taking into consideration how each segment and the relevant technologies scale.
- Modelling of technology purchase, deployment, operation and maintenance cost for all technology elements, across all segments, based on unitary costs and equipment scaling factors.
- Identification of deployment options, considering usage of alternative technologies at same segment.

CAPEX, OPEX and the TCO for the defined deployment scenario on a yearly basis need to be calculated. Additional financial figures such as Weighted Average Cost of Capital (WACC), Tax Deduction (% equipment cost) and CAPEX Amortization need to be considered in the yearly TCO.

From this point, considering the mapping between network segments, activities related to technology/ equipment purchase, deployment, operation and maintenance and the 5G/B5G Ecosystem roles illustrated in Figure 10, the CAPEX/OPEX/TCO (for all deployment options) are separately evaluated on a per segment and layer basis (see also Figure 10 for the technology segments) and on a per activity basis. Indicatively, the intermediate technoeconomic study can provide:

- **5G Mobile RAN segment:** equipment purchase cost, deployment cost, operation cost and maintenance cost; reflecting the incurred costs for the (Access) NOP, the CSP and the SA;
- **5G core and Edge segments**: equipment purchase cost, deployment cost, operation cost and maintenance cost; reflecting the incurred costs for the NOP, CSP, and SA;
- **hierarchical transport segments:** equipment purchase cost, deployment cost, operation cost and maintenance cost; reflecting the incurred costs for NOPs (separate for each hierarchical network level);
- **compute infrastructure segment:** equipment purchase cost, deployment cost, operation cost and maintenance cost; reflecting the incurred costs for the DCSP and DSP;
- and **the network segments deployed at the vertical site**, reflecting the incurred costs for the SA or the vertical site deployment across all layers (if provided by a single entity).

A high-level mapping of costs per 5G/B5G ecosystem actor role is provided in Table 7.

This cost segmentation can be used as guidance for extracting the TCO per actor role and actor operating on the same network deployment under study, in the same 5G/B5G ecosystem. In addition, it can provide guidelines on the cost breakdown and assist in deriving pricing for service provisioning between actor roles, while maintaining a technically consistent view across the complete network deployment under study. For example, while having a common network deployment and dimensioning studies across all layers and segments, an actor undertaking a specific role can focus on the incurred costs. Another actor combining multiple actor roles needs to assess the incurred costs across all the relevant network segments and layers for the undertaken costs and activities.

This can be helpful for actors when assessing their involvement in a relevant ecosystem and can be a major factor in driving the decision on the investment/ strategy/ role to be undertaken. In other words, the methodology can become a means to cross-validate 5G ecosystem formulations from a technoeconomic perspective. This analysis needs to be performed on a per deployment basis and for given scale and dimensioning assumptions.

Indicatively, combined business modelling and technoeconomic studies may reveal hidden costs that cannot be undertaken by a single actor – instead the cost may need to be shared among actors. It may reveal that sustainability of specific network deployments is achievable only in the context of multiple use cases/ verticals rather than in that of a single vertical. It can also reveal that specific technical choices at the 5G/B5G network layers may have an unequal impact on other underlying layers, and thus, the service provisioning roles. These are all aspects that affect if and how techno economically sustainable ecosystems emerge.

Table 7: Role-based cost-structuring of 5G deployments and services.

Costs	NOP	DCSP	CSP	DSP	SA	Vertical
Application Service Provisioning					X	
Application Service Deployment				X		
Application Service Operation				X	(X)	
Application Maintenance				X		
5G RAN equipment purchase	X (Access Operator)					
5G RAN Deployment	X (Access Operator)					
5G RAN Operation	X (Access Operator)		(X)			
5G Core/Edge equipment purchase	X (CN Operator)					
5G Core/Edge Deployment	X (CN Operator)					
5G Core/Edge Operation	X (CN Operator)		(X)			
5G Communication Service Provisioning			X			
5G Communication Service Maintenance			X			
Transport equipment purchase	X (per aggregation level)	(X)				
Transport Segment Deployment	X (per aggregation level)	(X)				
Transport Segment Operation	X (per aggregation level)	(X)				
Compute infrastructure purchase	(X)	X				
Compute infrastructure Deployment	(X)	X				
Compute infrastructure Operation	(X)	X		(X)		
Compute Services Provisioning		X		X		
Vertical Site Equipment purchase					X	X

In conclusion, there is a need to re-define the way technoeconomic studies are performed to capture the technoeconomic viability and sustainability of 5G/B5G ecosystems. They must take advantage of new business modelling tools and ensure that technological preferences and actor role selection is cross validated between layers and actor roles.

3.4. EVOLUTION TOWARDS 6G ECOSYSTEMS

From the previous analysis it is evident that certain technology and market developments of 5G/B5G networks have led to splitting network service/ activities/ operations and enabling various actor roles assuming these services/ activities/ operations, rather than them being undertaken solely by one actor – the Mobile Network Operator. In even more distributed and disaggregated forthcoming 6G networks, additional ecosystem actor roles are envisioned to address the following developments that may lead to new and/or evolving services:

- The evolution and commercial adoption of O-RAN and the evolution of RAN towards cell-free structures; based on which various RAN service approaches can be considered, e.g. (1) RAN as raw infrastructure resources, (2) RAN as virtualized resources or/ and (3) RAN -captured, -processed -exposed data to the roles of overlayers like NOPs and service customers.
- The evolution of transport network technologies that leverage the provided services from transport infrastructure-only resources to more intelligent services like virtual connectivity services, sensing data/ services etc.
- The integration of sensing in various network segments and the processing of data towards delivering versatile services, addressing various roles of the overlayers (with, e.g., network status insights, environment insights, activity insights)

In this context, it is the technology advancements that make room for an extended ecosystem model, further actor roles (as in [20][21]), and in turn varying and new cost structures. It shall be noted that the following envisioned evolutions will need to be accompanied by appropriate policies and regulatory frameworks that take into account numerous market and stakeholder aspects - these are not subject of the current work.

At the Infrastructure Layer in the 5G/B5G ecosystems service provisioning layers [7], the DCSP/IP role is considered. In 6G ecosystems we can assume additional roles undertaking the operation of RAN/O-RAN infrastructure (as hardware, as spectrum owner etc. and sharing the infrastructure to multiple VISPs/ NOPs). We can also consider new roles like the transport network segment infrastructure provider. Essentially, the actor role could be undertaken by those actors owning the relevant elements (transport, radio access, along with edge computing elements) and making them available as raw resources to NOPs. This can be enabled by allowing VISPs or NOPs full access to the control/management plane of the relevant elements. Illustrative deployment scenarios may entail public or commercial buildings and areas/locations with indoor RAN systems or transport infrastructure deployed and owned by the building owner, by municipalities, etc. Further deployment scenarios can be foreseen based on the trend where copper and fibre cabling are installed already in the construction of new buildings. With this, the infrastructure actor roles take on more CAPEX, and releases other actor roles from this burden by offering infrastructure as a service by e.g., leasing revenue models.

At Service Provisioning Layer, the VISP role offers virtualized network or cloud/edge computing resources through APIs. This role can be extended to include the operation of transport or radio access elements that are made available as network resources to one or multiple NOPs in a shared mode. The service provisioning actor role may need to closely collaborate with the corresponding infrastructure layer roles, to have a sustainable/ viable split of CAPEX/OPEX parts of the TCO of the relevant segments and to make use of economies of scale. As aforementioned, specific policies and regulatory frameworks would be needed to enable such roles splitting between actors.

At Network Operation Layer, the NOP role can be further split -both vertically and horizontally- into the RAN/O-RAN-operator roles and the CN operator or (traditional) NOP role. In this case, the RAN/O-RAN operator role undertakes the operation of the radio access elements and makes resources and/or additional services available to the roles of the overlayers. The latter can be either CN operators or other NOPs– to enhance network provisioning at the same layer- or even SP - to enable applications based on network sensing data.

At Service Provisioning Layer, the SP role (already split in CSP and DSP) can be broadened to include the provisioning of data services enabled by sensing data service provided across the layers and segments.

In this future landscape, we can envision ecosystems where the I4.0 actors can assume service provisioning roles (e.g., as infrastructure providers and sensing data providers) addressing/ interacting with the rest of the ecosystem actors in ways that are based on but not directly foreseen in the current analysis. This implies that business modelling analysis shall be considered as a continuously evolving process along with the technology progress, across the forthcoming generations of the networks.

4. SUMMARY AND RECOMMENDATIONS

To address the major changes in market dynamics driven by the move from 4G to 5G/B5G, this white paper has presented the implementation of best practice techniques in business model development. This approach allows those active in the 5G/B5G ecosystem to assess business opportunities and analyse the impact of these on the individual businesses and the ecosystem. Throughout the white paper, it was discussed that the same business analysis techniques are likely to be equally applicable as the industry moves from 5G to 6G, as 6G is expected to continue the application of distributed and disaggregated design principles seen in 5G/B5G. Therefore, the framework presented here will be important for assessing economic viability for actors operating in future 6G ecosystems.

This white paper focused on the implementation of the framework previously presented by the BVME sub-group of the 6G-IA [3]], using the example of the I4.0 vertical to guide the discussion. Application of the framework to other verticals is also possible, as it is generic and allows variations in use case specifics to be accounted for.

We have shown that the framework can be employed to provide multiple levels of detail to support actors to 1) better understand their position in an ecosystem, and 2) explore/ assess new business opportunities that can be created by changing their position in the ecosystem or by taking on additional/ adjacent actor roles. The key value of the framework is in allowing the implications of the resulting changes in the ecosystem dynamics to be better understood, supporting investment decisions. Such a tool can therefore be employed for strategic planning in anticipation of changes to the ecosystem activities of a company or as a result of changes by others in the ecosystem.

The initial steps of the framework enable analysis at a high level of abstraction, i.e., complex but still not extreme in terms of details, supporting actors in rapid exploration of feasible ecosystem configurations. The output from application of these steps revealed that the framework is capable of uncovering key insights affecting many strategic questions. For example, the analysis in the paper has identified relevant actor roles in the 5G/B5G provisioning ecosystem for I4.0 and suggested: 1) alternative ecosystem configurations, 2) different business models of the actor roles, and 3) the potential of an actor in one role, to move into other actor roles.

The framework also supports ecosystem actors in evaluating changes in costs resulting from ecosystem variations. The examples explored in the white paper use different scenarios to assess changes in market dynamics in terms of opportunities to, e.g., create synergies, competitive tensions and economies of scale. The analysis shows the necessary changes in the business models of the various actors impacted by changes in ecosystem dynamics.

This white paper also discusses approaches to assess the technoeconomic sustainability of ecosystem variations, which is a major factor affecting investment decisions, company strategy and role(s) to be undertaken in an evolving ecosystem. The approach to technoeconomic analysis outlined here provides structured guidelines on cost breakdowns and assists in deriving pricing for service provisioning between all actor roles, which varies with different deployment options. This approach also supports actors in ensuring that technical consistency is maintained across the complete network deployment strategy under study. In addition, it enables actors to identify hidden variances in cost structures and, in turn, increase their ability to exploit economies of scale and scope or identify specific sustainable ecosystem formulations.

For those applying this methodology for specific use cases, it is recommended to qualify all input information used for the analysis, such as actor roles in a specific ecosystem and their associated business models, actors taking on those actor roles, abilities of specific actors to provide different services or transition to different actor roles, etc. This will increase the quality of the answers to strategic questions. It is also recommended to use some time to explore and iterate with actor roles, configurations and business models using the initial steps of the framework, before deciding on one or more stable versions. This is to avoid the time-consuming collection of detailed data for actor roles and ecosystem configurations that are less plausible. That is, we recommend to carefully qualify, e.g., CAPEX requirements for different roles, type of competencies and human resources needed and levels of risk. When ecosystem configurations, actor roles and business models are stabilized, strategic business questions could be subject to more quantitative analysis.

This work can also provide the baseline and thus can be utilised, further extended and leveraged in the investigation of the market formulations and business aspects in the 6G era. Further work of the BVME-SG will focus on business modelling in 6G ecosystems, specifically considering the impact of on-going technology developments in the 6G research field and early 6G standardisation activities, including implications on business models driven by emerging topics, such as sustainability and integrated AI-data analytics for enabling advanced in-network and user-focused use cases.

5. REFERENCES

[1] 6G Industry Association, https://6g-ia.eu/

[2] Uusitalo, M., Bernardos, C. J., Kaloxylos, A., Bourse, D. A., Norp, T., Lønsethagen, H., Hecker, A., Rugeland, P., Papagianni, C., Bulakci, Ö., Li, X., Ericson, M., Anton-Haro, C., Massod Khorsandi, B., Ramos-Lopez, A., Frascolla, V., Marco, G., Gavras, A., & Trichias, K. (2024). European Vision for the 6G Network Ecosystem. Zenodo. https://doi.org/10.5281/zenodo.14230482

[3] Hallingby, Hanne Kristine, Gavras, Anastasius, Mesogiti, Ioanna, Bledow, Nona, Darzanos, George, Frizzell, Ronan, Breuer, Henning, Rokkas, Theodoros, Fernandez Vega, Luis, 2023, 5G and Beyond 5G Ecosystem Business Modelling. Available online, last visited 30 August 2024 https://zenodo.org/records/7640478

[4] Lorenzo, M. et al., 2023, Innovation Trends in I4.0 enabled by 5G and Beyond Networks. Available online, last visited 30 August 2024, https://5g-ppp.eu/wp-content/uploads/2023/10/Innovation-Trends-in-I4.0-enabled-by-5G-and-Beyond-Networks.pdf

[5] 5G-ACIA, 2022, White paper Industrial 5G Devices – Architectures and Capabilities. Available online, last visited 30 August 2024, https://5g-acia.org/whitepapers/industrial-5g-devices-architecture-and-capabilities/

[6] Gavras, Anastasius, Durkin, Patrick, Fletcher, Simon, Hallingby, Hanne Kristine, & Mesogiti, Ioanna. (2020). Business Validation in 5G PPP vertical use cases. Available online, last visited 30 August 2024 Zenodo. https://doi.org/10.5281/zenodo.3775405

[7] Hallingby, Hanne Kristine, Fletcher, Simon, Frascolla, Valerio, Gavras, Anastasius, Mesogiti, Ioanna, & Parzysz, Fanny. (2021). 5G Ecosystems. Available online, last visited 30 August 2024 Zenodo. https://doi.org/10.5281/zenodo.5094340

[8] Wikipedia, Fourth Industrial revolution. Available online, last visited 8 August 2024. https://en.wikipedia.org/wiki/Fourth_Industrial_Revolution

[9] Eurostat Statistics Explained, 2024, Business in the manufacturing sector. Available online, last visited 23 October 2024 https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Businesses_in_the_manufacturing_sector

[10] Cisco. What is OT security? Available online, last visited 23 October 2024 https://www.cisco.com/site/us/en/learn/topics/security/what-is-ot-security.html

[11] Cybersecurity and Infrastructure Security Agency, 2020, Securing industrial control systems: A unified initiative FY 2029-2023. Available online, last visited 23 October 2024, https://www.cisa.gov/sites/default/files/publications/Securing_Industrial_Control_Systems_S508C.pdf

[12] Cyber.gov.au, 2024, Principles of operational technology cyber security. Available online, last visited 23 October 2024 https://www.cyber.gov.au/sites/default/files/2024-10/principles_of_operational_technology_cyber_security.pdf

[13] Mahmood, Kashif, Gavras, Anastasius, Hecker, Artur, 2022, Non-Public-Networks – State of the art and way forward. Available online, last visited 30 August 2024 https://zenodo.org/records/7230191

[14] Parzysz, Fanny (editor), (2021). 5G-SMART, D1.3 Operator business models for smart manufacturing. Available online, last visited 28th January 2025. https://5gsmart.eu/wp-content/uploads/5G-SMART-D1.3-v1.0.pdf

[15] Osterwalder, A., & Pigneur, Y. (2010). Business model generation. John Wiley & Sons

[16] 3GPP TS 23.501, 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; System architecture for the 5G System (5GS); Stage 2

[17] E. J. Oughton and W. Lehr (2022). Surveying 5G Techno-Economic Research to Inform the Evaluation of 6G Wireless Technologies. IEEE Access, vol. 10, pp. 25237-25257, 2022

[18] Frank, H., Colman Meixner, C. E., Assis, K., Yan, S., & Simeonidou, D. (2022). Techno-Economic Analysis of 5G Non-Public Network Architectures. IEEE Access, 10, 70204-70218. Advance online publication. https://doi.org/10.1109/ACCESS.2022.3187727

[19] A. di Giglio and A. Pagano (2018). Scenarios and Economic Analysis of Fronthaul in 5G Optical Networks. Journal of Lightwave Technology (JLT), 2018.

[20] I. Mesogiti, G.. Lyberopoulos, F. Setaki, Andrea Di Giglio, A. Pelcelsi, L. Serra, Jim Zou, A. Tzanakaki, M.. Anastasopoulos, E. Theodoropoulou, (2020). Macroscopic and microscopic techno-economic analyses highlighting aspects of 5G transport network deployments. Photon Netw Commun 40, pp 256–268.

[21] Gutiérrez, J. et al. (2024). Seamless Integration of Efficient 6G Wireless Technologies for Communication and Sensing Enabling Ecosystems. In: Maglogiannis, I., Iliadis, L., Karydis, I., Papaleonidas, A., Chochliouros, I. (eds) Artificial Intelligence Applications and Innovations. AIAI 2024 IFIP WG 12.5 International Workshops. AIAI 2024. IFIP Advances in Information and Communication Technology, vol 715. Springer, Cham.

6. ABBREVIATIONS

Abbreviation	Full text
5G PPP	5G Public Private Partnership
6G IA	6G Smart Network and Services Industry Association
AI	Artificial Intelligence
API	Application Programming Interfaces
AR	Augmented Reality
AS	Application Supplier
B5G	Beyond 5G
BIK	Business Innovation Kit
BM	Business Model
BMC	Business Model Canvas
BVME	Business Validation, Models and Ecosystems
BVME-SG	Business Validation, Models, and Ecosystems sub-group
CAPEX	Capital Expenditure
CN	Core Network
CPE	Customer Premises Equipment
CSP	Communication Service Provider
DCSP	Data Centre Service Provider
DOI	Digital Object Identifier
DSP	Digital Service Provider
E2E	End-to-End
FBC	Flourishing Business Canvas
HW	Hardware
I4.0	Industry 4.0
ICT	Information and Communication Technologies
IoT	Internet of Things
NaaS	Network as a Service
NOP	Network Operator
NPN	Non-Public Network

NSaaS	Network Slice as a Service
KAM	Key Account Manager
KPI	Key Performance Indicator
ML	Machine Learning
OPEX	Operating Expense
O-RAN	Open Radio Access Network
PLC	Programmable Logic Controller
PNI-NPN	Public network integration with non-public network
RAN	Radio Access Network
SA	Service Aggregator
SBC	Sustainable Business Canvas
SDG	Sustainable Development Goal
SBA	Service Based Architecture
SI	System Integrator
SIP	Sustainability Innovation Pack
SNS-JU	Smart Network and Services Joint Undertaking
SW	Software
TCO	Total Cost of Ownership
UN	United Nations
VISP	Virtual Infrastructure Service Provider
VMT	Value Mapping Tool
VM	Virtual Machine
VR	Virtual Reality
WACC	Weighted Average Cost of Capital
XR	Extended reality

7. LIST OF EDITORS AND CONTRIBUTORS

Name	Organization	Association or Projects
Main editorial team		
Hanne Kristine Hallingby	Telenor Research & Innovation	6G-IA, IMAGINE-B5G, HEXA-X-II, 6GStart, SNS-OPS
Ronan Frizzell	Inlecom Commercial Pathways (ICP)	VITAL-5G, ACROSS, 5GMediaHUB
Ioanna Mesogiti	Hellenic Telecommunications Organisation	Eco-eNET, 6G-SENSES
Contributors		
George Darzanos	Athens University of Economics and Business	IMAGINE-B5G
Valerio Frascolla	Intel	VERGE, PREDICT-6G, 6G-XR, INTEND, Multix
Tasos Gavras	Eurescom	CENTRIC, 6G-SANDBOX, OPTI-GG
George Lyberopoulus	Hellenic Telecommunications Organisation	6G-EWOC, SUNRISE-6G, ENVELOPE
Håkon Lønsethagen	Telenor Research & Innovation	6G-IA, FIDAL, SNS-OPS, 6GStart
Marja Matinmikko-Blue	University of Oulu	Hexa-X-II, 6G-MUSICAL
Pooja Mohnani	Eurescom	SNS ICE
Grigor Parangoni	BEIA	FLEXI-CROSS
Ana Petrache	BEIA	VITAL-5G, ECYBRIDGE
George Suciu	BEIA	VITAL-5G, FOR-FREIGHT
Victor Suciu	BEIA	SOLID-B5G
Elina Theodoropoulou	Hellenic Telecommunications Organisation	6G-EWOC, ENVELOPE

Contact: Office@6g-ia.eu

Website: https://6g-ia.eu/